With W. Owen Travis' compliments

Bacterial . . . . .
Sewage Purification.

The Hydrolytic Tank
and Oxidising Beds.

An Enumeration of Experiments
and an Ennunciation of principles
having special reference to

The BACTERIAL PURIFICATION of SEWAGE

in

The Hydrolytic Tank

and

Oxidising Beds

BY

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AND

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Conclusions and Propositions

Based upon Researches into the

Purification of Sewage.

THE conception of "The Hydrolytic Tank and Oxidising Beds" is the result of a close study of the numerous experiments conducted at Lawrence under the ægis of the State Board of Health of Massachusetts, and published by that Board in a series of works which, in their entirety, constitute a classical record of the bacterial purification of sewage.

This being so, an acknowledgment of the source from whence the ideas were derived and a recital of the conclusions having special reference thereto are, as a matter of common honesty as well as of courtesy equally desirable.

The conclusions come to by the Officers of the State Board relating to

ANÆROBIC TREATMENT

briefly stated are as follows:—

a. "The results obtained (in the septic tank) during 1899 (when owing to the low rainfall considerably stronger sewage had to be dealt with) have strongly indicated that the greater the amount of organic matter in the sewage entering a septic tank the greater will be the percentage reduction of organic matter by the tank treatment." This observation suggests the idea that "where exceedingly large volumes of sewage are to be purified, as in the case of the

sewage of a large city, this sewage could be passed through ordinary settling tanks, so constructed that the sludge settling to the bottom of these tanks could be flushed into a septic tank and this sludge alone be treated by septic tank action, instead of attempting to treat the whole of a city's sewage. Following up this idea, a septic tank was put in operation during September 1899, to receive the strong sludge from settled sewage." The results of this experiment, up to and including the year 1901, were "that the tank contained about 20 per cent. of the organic matter of the sewage which had entered it during its period of operation," and "as the effluent contained about 22 per cent., . . . about 58 per cent. was liquefied or otherwise changed and given off as gas by the tank action during its period of operation." This was a rate of purification which exceeded that occurring in an ordinary septic tank during the same period, notwithstanding that in operating the tank the sewage was not moving through continuously, as the effluent passed from the tank only during the short time each day that concentrated sewage was being passed into it.

b. "During the first winter of its operation there was a constant accumulation of sediment within the tank," which was believed to be "due to the long period that the sewage remained in the tank at that time, and the consequent diminution of bacterial growth on account of the production of toxins." It is probable, however, that the absence of the pipe openings (*i.e.*, absence of ventilation,) upon the top of the tank, which were subsequently introduced,

prevented the escape "of certain gases that, when held in solution in a closed tank, were inimical to the continuation of bacterial life."

c. "The matter in suspension in sewage is the chief factor in clogging the surfaces of . . . filters. . .. By the action of the septic tank a very large proportion of these matters in suspension is eliminated from the sewage when it flows from the tank. A certain proportion changes its form and goes into solution in the sewage, while another portion is changed to the gaseous form and escapes; while undoubtedly at times, as has been repeatedly noticed at Lawrence, considerable very finely divided solid matter comes from the tank. This occurs at times when the movement of the gas in the tank disturbs the sludge, and, while only lasting for a few minutes at a time, causes considerable solid matter to flow out in suspension."

d. "It is evident, from our experiments, that the bacteria in the tank that do the larger proportion of the work live on the sides, bottom and top of the tank, where organic matter accumulates, and where they are found in enormous numbers compared with the numbers found in the liquid that is passing through the tank;" hence an experiment was inaugurated in 1899, "in which sewage was passed upwards through a tank filled with broken stone, in order to afford a very extensive foothold and breeding place for the necessary classes of bacteria. Comparing the average analysis of the effluent of this anærobic tank or filter with the average analyses of

the effluent of the septic tank A, we see that the percentage reduction of organic matter was greater in the former, and that an effluent was produced containing a smaller amount of matter in suspension and hence more easily filtered at high rates." In 1901, when the applied sewage passed through the filter in about six hours, or nearly four times as fast as similar sewage passed through the septic tank, it was found that "the principal obstacle in operating an anærobic filter such as this, compared with the operation of a septic tank, is the greater difficulty in removing accumulated sludge, if we assume, as seems reasonable, that in both cases sludge will (when treating most sewages, eventually) accumulate to such an extent that its removal will be imperative."

These conclusions clearly indicate the following propositions:—

1. That as the liquid portion of water-carried sewage contains matters in solution only, and as the water has already fulfilled its principal function, viz.: the conveyance of the grosser particles, so it should be permitted to pass through the tank in the limited time necessary for purely sedimentary purposes.

2. That as the suspended matters of the sewage only require to be subjected to a prolonged digestive process, so these matters, together with the minimum amount of liquid which is found to be necessary for the free flowing of the particles, and for the carrying away of the liquefied products, should alone undergo the septic tank or hydrolytic treatment.

3. That as in any sedimentary tank some of the matters in suspension, whose specific gravity differs little from the liquid will not be deposited, and as in all septic tanks considerable quantities of deposited sludge, disturbed by the gases of decomposition, will constantly flow out of the tank with the liquid so a further purification in an upward anærobic filter is absolutely necessary.

4. That as the gaseous and volatile products are, like the liquid products, equally subversive of micro-organismical hydrolysis; as they are the cause of the strong odours which prevail in a septic tank effluent; and as they are detrimental to the subsequent oxidation in contact or other ærating beds, so they should be removed, by exhaustion, from the tank as they are formed.

5. That as sludge must accumulate, so means must be provided for its systematical withdrawal. Any attempt to establish a so-called equilibrium is futile, it is, in fact, but a method of evading the issue, and of throwing upon the subsequent treatment matters which ought to be effectually dealt with in the tank.

The Hydrolytic Tank has been devised in conformity with, and in order to secure the advantages of the foregoing propositions.

The conclusions of the Massachusetts State Board Officers relating to

ÆROBIC TREATMENT

may be stated as follows:—

a. "All our studies have shown that it is extremely desirable that the sewage, before passing to contact filters, should be treated by some method, such as settling, straining, or bacterial action in the so-called septic tank, that will remove from it as much as possible of the matters in suspension: and they have apparently proved that, if contact filters are to be kept in operation for a considerable number of years, they must receive sewage which has been clarified in some such way, or else the filter must be of such coarse and smooth material that all suspended matter will pass readily through it."

b. "When sewage in an advanced state of putrefaction is applied to a contact filter, and the entire open space of the filter filled with this sewage, it is possible that oxidation may be so rapid that the supply of oxygen within the filter will be exhausted before the process of nitrification has had time to begin. That is to say, even if the nitrifying bacteria are in the sewage when it is passed to the filter, or in the filter at the time of the introduction of the sewage, their power may be entirely overcome temporarily by a lack of oxygen. . . . It is evident that, if sewage in the condition of septic sewage B upon the date of the first experiment flowed into a contact filter, filling it entirely, no nitrification could be expected to take place within

the filter, as the oxygen with which it would come in contact would probably not be more than enough for the first rapid oxidation, this quick oxidation being probably a chemical action rather than the bacterial oxidation upon which nitrification depends. When such sewage . . . is run in a comparatively small volume upon the surface of intermittent sand filters, however, it remains upon the surface in most instances long enough for considerable oxidation to take place, and it meets a large volume of air as it slowly passes through the filter and hence nitrification occurs."

c. "As, moreover, this rapid absorption of oxygen did not cause a change in the character of the organic matter of the sewage that could be readily detected by the ordinary chemical analysis, experiments were undertaken to show whether or no it was the oxidation or saturation of gases. . . . These experiments were repeated, and seemed to prove conclusively that the rapid absorption of oxygen was by gases or by organic matter that sterilizing by heat had so changed that it was not easily oxidized rather than by bacterial action." This "makes clear one of the reasons for the difficulty of nitrifying certain septic sewage. Can we not, however, satisfactorily explain these results by assuming that we have groups of bacteria of different characters, producing ptomaines that seriously interfere with nitrification? We know that . . . the condition obtaining in tanks must be quite different one from the other, and the organic matter in the sewage must be worked over to a

different extent or by different bacteria, giving different end products. . . . It is certain that, if the anærobic process is carried too far, there may be a formation of distinctly poisonous bodies, which might prevent nitrification."

d. "The effluents of properly constructed and operated contact filters contain very little organic matter in suspension. When the effluent flows from a filter, air is drawn into the filter again and fills the open space. Consequently a partial oxidation of the organic matter left within the filtering material proceeds until this oxygen is exhausted, when the open space is completely filled with the chief products of this oxidation,—namely, carbonic acid, marsh gas, nitrogen of the air primarily present and nitrogen liberated during decomposition,—and the filter will remain with its open space filled with these gases until they are removed by the introduction of sewage or air. This condition reached, the activity of the oxidizing and nitrifying bacteria within the filter ceases and anærobic actions begin."

e. "It seems probable that the organic matter, both that in solution and that in suspension, is worked over and digested by the bacteria in the filter, first by the anærobic and then by the ærobic bacteria. By this process the matter is, in the first place, rendered unsuitable food for the anærobic bacteria and perhaps toxic to them. When in this condition, however, it is suitable food for ærobic bacteria, which rapidly at first and then more slowly change it to this stable condition."

f. "These studies have proved quite conclusively that, while the intermittent continuous filter of coarse material is perhaps more difficult to operate on account of the necessity of uniform distribution of the sewage over the surface, etc., yet . . . they can be operated at higher rates than contact filters, and will generally give better purification results: that is, nitrification within them is generally more active, the organic matter remaining in the effluents more thoroughly changed, and the appearance of the effluents somewhat better. . . . The reason (for which) is undoubtedly the greater volume of air that comes into contact with the sewage as it passes through these filters, the thinner streams of sewage, . . . continually passing in thin layers over the filtering material, and are thus continually in contact with the bacteria upon the filtering material and also in contact with air; while in contact filters the main volume of sewage is, when the filter is standing full, not in contact with the material, but filling the voids between, and ærobic bacterial action is limited by the volume of air remaining in the filter after filling as much as possible of the open space of the filter with sewage."

g. "Another interesting and practical point ... is that the matter in suspension . . . accumulates more slowly within the intermittent continuous filter; for when reaching a certain degree of change or bacterial oxidation, it is continually falling from the filtering material in flakes and appearing in the effluent. In the contact filter . . . this tendency to loosen

from the material is less marked, and hence these filters lose a greater percentage of their open space,—a serious matter in all filtration at high rates by means of coarse filters, but more especially so with contact filters," as the rate really "depends upon the open space."

h. "A difference of a few degrees in the temperature of the sewage entering the bed causes a considerable difference in the degree of nitrification taking place within the filter in winter."

i. "We have sometimes found the highest nitrification and the smallest number of bacteria when there was a large supply of the ammonias in the effluent. This would indicate that the most complete destruction of bacteria was not due to a failure of food, so far as that may be supplied by the free or albuminoid ammonia of these effluents, but was rather due to the process of the formation of nitrates,—the burning process. We have thought that their destruction might be due to being deprived of oxygen that was used in the oxidation of other organic matter; but it may be due to their own oxidation,—to their being burned."

These deductions substantiate the following propositions:—

1. That as a 'contact bed' must infallibly become inoperative when treating crude sewage, owing to the accumulation of sludge on its surface and in its interior, so some method of clarification must be resorted to in the first instance.

2. That as the purification effected in a 'contact bed' is dependent upon a cycle of anærobic and ærobic actions, so a good 'contact bed' must necessarily be an imperfect ærating bed.

3. That as the effluent from a septic tank contains "organic matter in such a condition and gases of such a nature that the oxygen primarily present in the contact filters was exhausted by direct oxidation of carbonaceous matter before nitrification could become established," so a septic tank effluent should not be submitted to 'contact bed' treatment, but to some more perfect means of æration.

4. That as the purification results of an intermittent continuous filter are uniformly superior to those of a 'contact bed,' in quantity as in quality, so the latter must go, and methods adopted in order to overcome the difficulties incidental to the working of the former.

5. That as the gases produced in the contact or other ærating bed, equally with those contained in a septic tank effluent interfere with the purification results, so provision must be made for the systematical exhaustion of those gases from the bed, as well as for the introduction into the bed of fresh air.

6. That as the nitrification results are adversely affected by cold weather, so means must be taken to prevent any great loss of the heat in the sewage, and, during the continuance of cold weather, the air introduced into the bed should be heated.

7. That as "the period of greatest destruction of the ordinary sewage bacteria corresponds closely with the time of most active nitrification and most complete æration," so the cultivation of the nitrifying organisms, and the acquisition of the freest admission of air, must constitute appropriate means for inhibiting the passage of living pathogenic germs.

The **Oxidising Beds** have been so designed as to be in compliance with the requirements of the above-mentioned propositions.

The following extracts from the voluminous literature published in this country on the bacterial purification of sewage, are adduced as a confirmation of the foregoing statements, and in order to bring out particular facts relevant to the method of treatment herein advocated.

Professor Frank Clowes, in his Fourth Report to the London County Council, 1902, summarises the evidence given before the Royal Commission on Sewage Disposal as follows:—

"The Commission have now published their minutes of evidence, and a careful perusal of the evidence given by the independent experts, including engineers, bacteriologists and chemists, shows that they are in general agreement in maintaining that the only known method of producing a satisfactory sewage effluent on a large scale is by the adoption of one or other of the various systems of bacterial treatment.

"The bacteriologists gave evidence to the effect that the purification of sewage was a combined anærobic and ærobic process, and that the best results were obtained by a more or less perfect anærobic treatment, followed by an ærobic treatment.

"The great majority of the witnesses agree that crude sewage cannot be successfully treated by contact beds alone, since, although the results are good and a non-putrescible effluent is produced, the liquid capacity of the beds diminishes so rapidly that they soon become useless.

"In order to prevent this choking of the beds and to maintain their liquid capacity, almost all of the schemes described include a preliminary process of sedimentation which is in most cases also rendered an anærobic or so called "septic" process. Its main objects are to free the sewage from mineral suspended solids and to cause the complex suspended organic solids to pass into solution and to become simplified in nature. In the subsequent ærobic process, usually carried out in coke-beds, opinion is divided as to the respective merits of a continuous and of an intermittent supply. It must be said that those who support the continuous treatment make out a good case so far as the results obtained are concerned. The continuous system seems to produce nitrates in larger amount than does the intermittent system, but at the same time the effluent is by no means as free from suspended solids which appear to be washed through the bed. Some special method of distribution of the liquid to the bed is required by the continuous treatment, and this is not only a cause of additional expenditure but also of additional trouble in maintenance as compared with the intermittent system of supply."

Though Professor Clowes is "in loco parentis" to the contact bed, yet he reports to the London County Council, that—

"As a result of the whole series of experiments, it was proved that the crude sewage of London could not be satisfactorily dealt with in coke-beds unless it was subjected to a preliminary settling process; since, although the coke-beds deliver a satisfactorily purified effluent, they choke up very rapidly if they are constantly charged with crude, unsettled sewage."

Professor Boyce, in the Second Report of the Royal Commission on Sewage Disposal, 1902, states:—

That a combination of anærobic and ærobic processes is the most advantageous, "provided that the septic tank is made more perfect than at present and suspended sludge be prevented from passing over on to the beds."

That "the experience is hardly long enough to enable us to say definitely that the septic tank is the best means of bringing about the sedimentation and the destruction of the solid material of sewage."

"That the septic tank will gradually sludge up and the more the tank tends to sludge the more sludge in suspension is carried over into the contact beds, owing to the disturbance of the gradually rising floor of sludge."

That "our experiments at Leeds and Manchester show that the B. Coli diminishes during the stay in the septic tank, and experiments conducted in the Laboratory show that the septic tank liquor is inimical to the B. Coli and therefore to the other more delicate pathogenic bacteria."

Dr. Sims Woodhead, as the result of his experiments, recognized:—

"That there was a sharp line of distinction between the work done by the anærobe, and that by the ærobe, and that the two processes should be kept as separate as possible."

Drs. Kenwood and Butler state:—

That "while upward filtration offers a better prospect of effecting the separation and solution of the suspended matters of sewage, it, at the same time, reduces the pollution of the effluent better than any system which aims at their removal by digestion in a hollow chamber, such as a septic tank."

Dr. G. Reid expresses the opinion:—

That "filtration, not contact, is undoubtedly the best system, but the question of distributing the effluent, especially from a septic tank, was a very difficult one unless the outfall was a long way from any population. This question would have to be settled, because he could not help thinking that filtration ultimately was going to be the system of biological treatment adopted all round. Contact would go and filters would stay, and an efficient method of distribution would have to be brought out—an especially difficult task if the first part of the process was going to be conducted anærobically and the outfall was not well removed from the population."

Major R. H. Firth states as the result of personal work in conjunction with his Colleague, Major Horrocks:—

"That the enteric bacillus is not only a much more hardy micro-organism than many have supposed, but is capable of assuming a vegetative existence, and surviving in ordinary and sewage-polluted soil for periods varying from fifty-three to sixty-five days" . . . which demonstrates "the risks attending the dry earth or pail closet system of excretal removal;" explains "how these portable middens may be, and often are, foci of enteric infection, and I think warrants the conclusion that any installations of the kind in towns or large communities are most objectionable. In the water carriage system, the dangers of local infection are practically *nil,* but the final management and disposal of the sewage under certain methods suggests elements of risk. . . . The situation therefore is practically this, that effluents from biological or septic tanks, from bacteria beds and land, are potentially dangerous liquids, and, so far as their contained fauna is concerned, but little different from original sewage. I make this statement and emphasize it in no reactionary spirit, for I am fully convinced that in the biological or natural method of sewage treatment we have the true clue towards solving the sewage problem." . . . The question remaining still to grapple with is that of "sterilizing the effluent, or at least freeing it from living pathogenic germs."

Dr. Rideal, in his excellent work on "Sewage and the Bacterial Purification of Sewage," points out:—

That "the continuous action is on the right principle, as I have often emphasized the disadvantage of intermittent working in alternating and confusing the bacterial actions. . . . In the case of contact beds, except when they are used in series, there is no differentiation of the organisms in relation to the food supply, because although the conditions are changed from being purely anærobic to those more or less favourable to ærobic action, these are conducted in such a way as to provide neither condition continuously."

That in the third stage of bacterial purification "an abundance of carbonic acid is formed by fermentations due to other classes of bacteria. I have found in several bacterial filters intended to be ærating and final, such a large quantity of carbonic acid as must seriously retard their nitrifying action; the result being a deficiency of nitrates in the effluent. . . . A point to notice is that with the presence of gaseous carbonic acid there must be an additional quantity, proportional to the vapour tension, retained dissolved by the liquid in the interstices of the coke. Several observers have proved the inhibiting action of carbonic acid on bacteria, especially those which are oxidising, therefore it is important when the third or oxidising stage is reached, that the carbonic acid should be removed by free circulation of air as soon as formed, or the failure of nitrification noticed in so many of these filters will follow."

Dr. Rideal in the section on the survival of pathogenic organisms points out, from the results of his own experiments made prior to 1900—

> "That the greater the æration and nitrification, the less is the possibility of the survival of pathogenic organisms."

A perusal of Dr. Rideals' work will demonstrate the fact that the conclusions which have been culled from the Reports of the Massachusetts State Board of Health, and the deductions and propositions which have been based thereupon and which are herein recited are in entire accord with the main line of reasoning adopted in that work.

There remains but to add that, as in the human economy, the liquefaction of the albuminous and the other food stuffs by hydrolysis, is a condition necessarily antecedent to the absorption of the liquefied products into the system, and to the final oxidation in the tissues. So in the bacterial purification of sewage, a continuance of the hydrolytic process upon the undigested and indigestible matters of food, and upon the other suspended organic matters in sewage is a condition precedent to the final oxidation or burning up thereof. And as in the analagous case of human digestion, so in the natural purification of sewage, a place must be provided for the reception of the whole volume of the material to be acted upon, in which

place opportunity must be given for the earliest removal of the liquid matter and of the matters in solution; where the insoluble matters may remain during the digestive processes; from whence the matters sufficiently acted upon may be withdrawn; and out of which the hydrolised products will pass at the earliest moment.

DESCRIPTION OF

THE HYDROLYTIC TANK

and

OXIDISING BEDS.

Plate I. illustrates the "Hydrolytic Tank" which is divided into two parts.

The first part consists of two "Sedimentary Chambers" laterally situated and a central "Liquefying Chamber.

The sewage having first passed through a "Detritus Tank" enters the Sedimentary Chambers and traversing their length emerges therefrom over the weirs . *a a* . as indicated by the arrows. The time thus occupied (about five hours) suffices for the deposition of the suspended solids of the sewage. The deposited matters gravitate through openings . *b b* . at the bottoms of the dividing walls of the chambers and are accompanied with and accelerated by a proportion of the liquid being allowed to flow into and through the Liquefying Chamber. The section of the latter chamber below the level of the openings . *b b* . provides for the reception and accumulation of the deposited sludge pending its hydrolysis; the section of the chamber above the openings . *b b* . provides for the flow of the liquid and for the carrying away of the gaseous and liquid products

due to the hydrolysis of the deposited matters; the time occupied by the liquid in passing through the Liquefying Chamber being about fifteen hours. The relative flow of the liquid through the Sedimentary and Liquefying Chambers, both as regards velocity and quantity, is regulated by the relative capacities of the chambers and the widths of the respective weirs.

When the sludge has been sufficiently hydrolised or when its level approaches that of the openings . *b b* . the valves . *c c* . are successively opened and the lowest portion of sludge, that most digested, is forced through the sludge pipe . *d* . by the head of the liquid in the tank.

The effluents from the Sedimentary and Liquefying Chambers, and such finely divided or light sedimentary matters as may be carried therewith, overflowing the weirs . *a a* . drop into and become intimately mixed in the channel . *e* .

The second part of the Hydrolytic Tank, to which the liquid now passes, consists of a series of "Upward Anœrobic Filters" filled with flint stones or other material of suitable size. The mixed effluent is deflected to the bottom of the first filter, as indicated by arrows and passes upwards through the material (leaving the suspended matter adhering thereto) and overflowing the dividing weir is again deflected to the bottom of the second filter, passes through the material of the second (and third or more filters) and finally issues from the tank at . *f* . occupying during its progress through the second portion of the tank about three hours.

Should there be any accumulation of sludge in this part of the tank provision is made for its withdrawal in a manner similar to that described in connection with the Liquefying Chamber.

The Hydrolytic Tank is, as a whole, covered in, and the gases and volatile products generated therein, are continuously and systematically exhausted by means of a fan in order to keep the gas tension within the tank, and that of the contained liquid at as low a pressure as practicable, so as, on the one hand, to avoid the possibility of any explosion, and on the other to obviate some of the difficulties incidental to the objectionable odours, and to the subsequent treatment of the effluent.

From the Hydrolytic Tank the effluent is taken to "Oxidising Beds" (illustrated by diagrams on Plate II.) on to which the liquid is delivered intermittently by means of a syphon arrangement. The liquid is collected in Syphon Chambers of such a capacity that each is filled in not less than say ten minutes, and when full the contents are discharged automatically by means of the syphon *.g.* on to the upper or Nitrosifying Layer of the beds and percolating therethrough, falls on to and through two or more Nitrifying Layers fixed underneath, the final effluent being drawn off by the channel *.h.*

The even distribution of the liquid on to the upper layer is secured by having the Syphon *.g.* of such a discharging capacity as to deliver the liquid with a rapidity to flood a bed, the surface of the latter being protected from disturbance by perforated tiles, wire netting

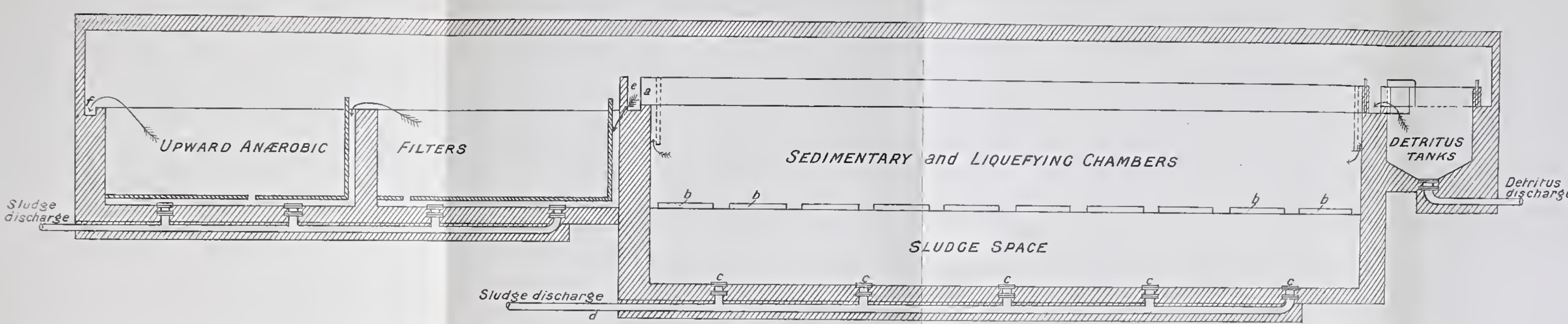
or other device. The liquid capacity of the Nitrosifying Layer should be about equal to that of one discharge from the Syphon Chamber, and the layer itself should be formed of coarse sand or other suitable material of such grade as to allow of one charge of liquid to completely percolate through before the next is ready.

The Nitrifying Layers should be formed of coarse gravel or other suitable material of such grade as to provide convenient space for the growth of the nitrifying organisms so that the phagocytic action and the dependent organismal filtration may be developed to the fullest extent, and at the same time that provision be made for efficient æration.

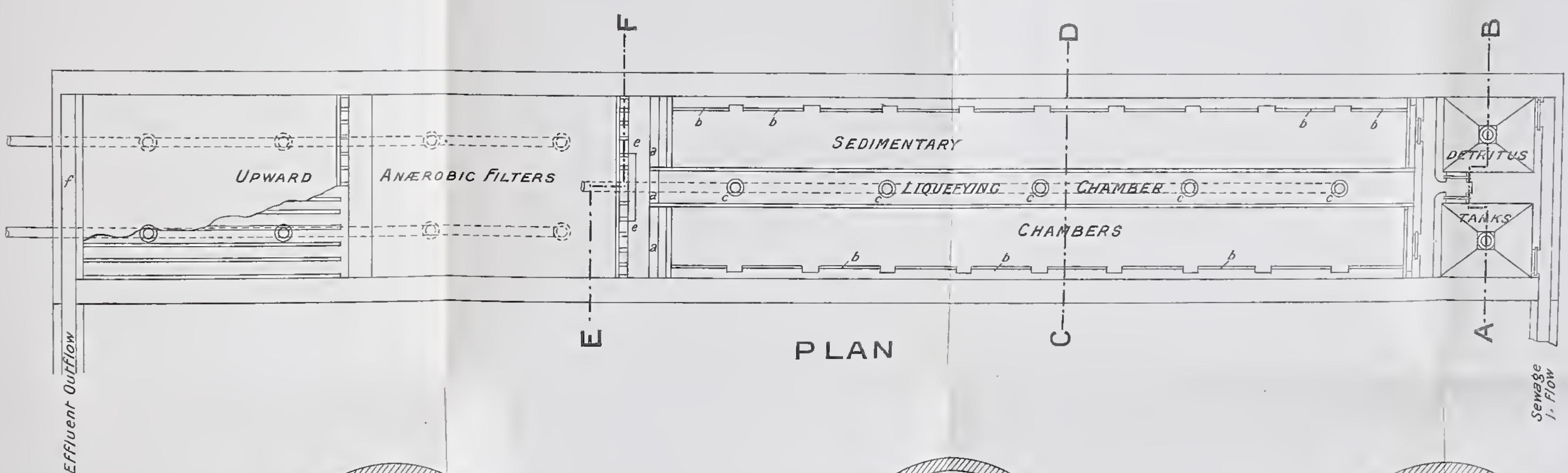
The successive layers of the Oxidising Beds are separated from each other by spaces through which a current of air is drawn by a fan, and through which the liquid falls from one layer to the other, thus providing the necessary oxygen for the lifework of the organisms and a means of conveying away the gases produced thereby.

By admitting the air to the beds through a pipe or conduit, the volume can be controlled and also the air can be heated in order that during severe weather the best conditions may be established for the maximum activity of the organism.

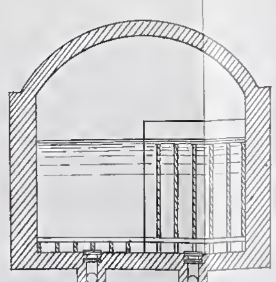
HYDROLYTIC TANK.



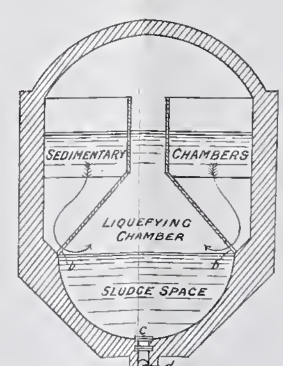
LONGITUDINAL SECTION



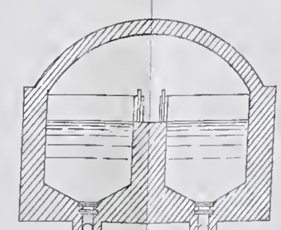
PLAN



TRANSVERSE SECTION E. F.
through Upward Anærobic Filters.

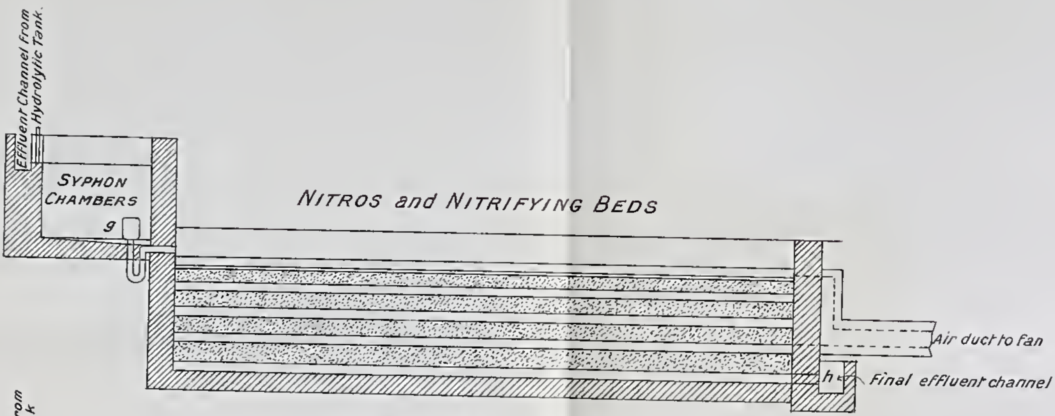


TRANSVERSE SECTION C. D.
through Sedimentary and Liquefying Chambers & Sludge Space.



TRANSVERSE SECTION A. B.
through Detritus Tanks

OXYDISING BEDS.



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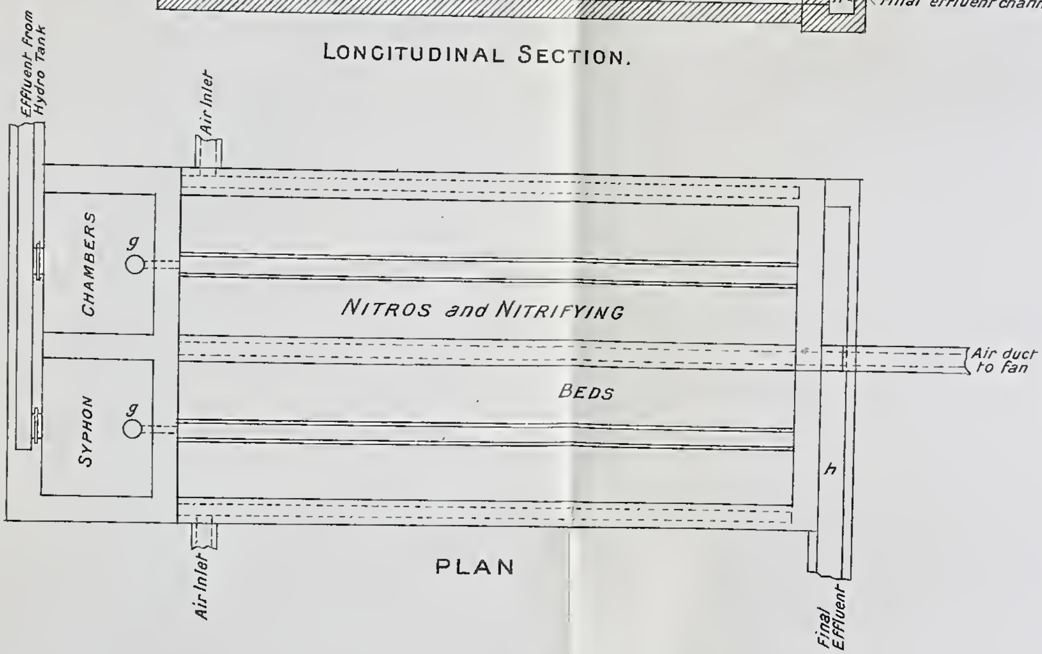

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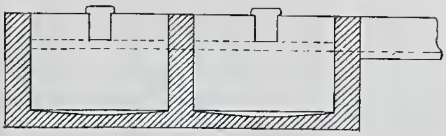
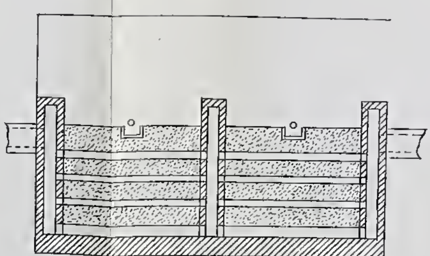


TRANSVERSE SECTION
through Syphon Chambers



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